NEW ELECTR0NICS FOR THE 3M MASTER TAPE RECORDER

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In 1964 the 3M Company introduced the 3M Brand Professional Recorder, a state-of-the-art audio-range tape recorder that featured a closed-loop tape drive and solid state Dynatrack electronics. The low wow and flutter of the transport and the extended dynamic range of the electronics created a favorable demand for the machine in the professional market. Because of this, a decision was made to revise the machine to make it suitable for production in large quantities. The second generation version was introduced in 1965. The major changes were the use of a precision machined aluminum casting in the transport and the addition of compatible NAB electronics. This new machine proved to be very versatile, but the electronics module was difficult and expensive to manufacture. For this reason, a study was initiated to design a new module that would be simple, inexpensive, and equal in quality to the existing version.

At the start of this study, it became obvious that several factors enter into the manufacturing cost of the electronics module. Each of these aspects must be considered to achieve a package with a high overall manufacturing efficiency commensurate with the end use:

1. Chassis costs - How much does it cost to fabricate the chassis parts, apply finish, and assemble a finished chassis?

2. Electronic components - Both cost of discreet components and the time necessary to install them must be considered.

3. Wiring cost - The total number of wires, the number of shields requiring termination, the use of crimp terminals versus solder lugs, and the accessibility of the various connectors all enter into this cost.

4. Quality control - The total time necessary to inspect each assembly for errors becomes important. Printed circuits are easiest to check; harness wiring, the most difficult.

The rigor with which these guidelines are followed will determine the success of the final design. The following description covers the more interesting aspects of the new module design and illustrates the type of decision that must be made. First, the packaging problem will be described, and then a brief circuit description will be given.

CHASSIS

The most important step in the initial design of the module was a decision to make all of the controls such as switches, gain controls, and indicator lamps part of the printed circuit card assembly. Also, the number of cards would be reduced from eight to one or two. Since each card assembly must contain over one hundred components, the surface area must be quite large. Boards with printed traces on both sides were ruled out because of cost and lack of dependability with plated through holes. A minimum of 20 pins on each board would be required to provide the necessary interconnections. The use of a single row 20-pin connector prohibits vertical boards since the connector length is an inch greater than the total module height.

Once the use of horizontal cards was established, the next problem was the placement of the cards within the module. The best locations for the card would be against the bottom of the module with the components above, or at the top of the module with the components hanging downward. Since all of the connectors for line and head cables are near the top of the chassis on the rear panel, a card at the top was chosen to shorten the lead lengths from the card connector to the external plugs. This placement also facilitates assembly procedures and eliminates the need for wiring jigs.

The use of two cards was selected as the best compromise between simplicity and serviceability. The left card assembly contains the record amplifier, playback preamplifier, record relay, and overdub circuitry. The right card assembly contains the line amplifier, bias and erase buffer amplifier, A-B switching circuits, and meter monitoring switch.

The remaining components - the output transformer and the VU meter - are mounted in the center of the module. The bracket to which they are attached also serves as a structural member, a card guide for each card, and an anchor point for the card assembly latch.

Each printed circuit card is attached to its mating front panel at three places. This assembly forms a "T"-shaped structure that adds extra rigidity to both the front panel and the printed circuit card. The front panel is slotted to allow access to the calibration controls. During normal operation the slots are covered by a trim strip, but the strip can be removed by simply releasing the two panel snap-latches. These latches also serve as handles to aid removal of the panel and card assembly from the module.

The lightweight sheet metal parts for the module form a monocoque structure that is extremely rigid. The "V"-shaped rear panel acts as the main beam of the assembly, and the four upright members and the top and bottom sheets form a monocoque box. If the module is supported by blocks at each end, the center of the module will bear a load of more than 150 pounds without any extreme deformation.

The various fasteners were chosen with effectiveness, cost-, and installation ease as the criteria. These fasteners include eyelets for securing card guides, connectors, and switches; and self-locking nuts where screws are required.

The following sections describe the electronic circuitry that has been developed for the new module. Where possible, a comparison is made with the present circuits.

RECORD AMPLIPIER

Three changes were made to the current record circuit:

1. The input transformer impedance and turns ratio were changed to give a higher voltage level to the first transistor,

2. The gain pot was placed before the input transformer, and

3. The monitor circuit is fed from the first transistor emitter rather than in parallel with its base.

The input line feeds through a high impedance record gain control to the primary of the input transformer. Since the minimum input level is -20 dBm with the record gain control set at maximum, the transformer never sees more than a -20 dBm reference level at 0 VU. For higher line levels, the gain control attenuates the signal to the desired -20 dBm level.

The transformer secondary feeds an amplifier stage that brings the signal up to a high level before insertion into the R-C pre-emphasis network. A junction field effect transistor that acts primarily as a low-noise impedance transformer follows this high impedance circuit.

The FET output is coupled to a Darlington output pair. The output stage collector feeds the head through a series resistor to achieve constant current recording. The emitter of the output is bypassed with a pair of transistors connected as diodes that act as a third-harmonic distortion compensating circuit.

The feed to the line amplifier for source monitoring is extracted from the first stage emitter. An extra amplifier stage allows monitoring at any output line level up to +14 dBm.

PLAYBACK PREAMPLIFIER

The new playback preamplifier is quite similar to the present circuit. The head feeds a two-stage equalizer amplifier that has adjustable high frequency and low frequency gain. This is followed by a phase rotation network to compensate for phase shift due to the record head characteristics. A low impedance output is derived by using an emitter follower. Equalization and phase correction are selected by a reed relay controlled by the transport speed switch.

Some minor changes were made to decrease cost and improve performance. The use of an active filter on the power supply bus allows the operating voltage to be raised from 18 volts to 26 volts. This raises the clipping level of the phase corrector to allow the use of future heads that have a higher output level.

The introduction of less expensive epoxy-packaged transistors permitted savings of more than one order of magnitude on the input transistor. Similar savings were also made in the other circuits, but many of the transistors were already low-cost epoxy packages in the previous design.

LINE AMPLIFIER

The line amplifier is a complementary symmetry amplifier using a matched pair of germanium transistors in the output. For this application, the limited bandwidth of the germanium transistors is unimportant and their relatively high gain allows a direct drive without the usual matching transistor for each output element.

The existing machines use a matching network to make the line amplifier output look like a 600 ohms source. The new modules use a low impedance output that conserves the 5 dB lost with this network. This means the output transistors do not dissipate as much power at the +28 dBm maximum level.

A large amount of overall feedback is used to achieve flat response and low distortion. The maximum distortion at +28 dBm and 20 Hertz is less than 1%. Response is down 3 dB at 55 kilohertz due to transformer loss and controlled rolloff in the amplifier.

BIAS AND ERASE AMPLIFIER

All 3M master recorders have used a master oscillator in the transport and buffer amplifiers in each electronics module. The current machines have two separate amplifiers for bias and erase because the erase buffer is used for the Dynatrack bias supply when the machine is used for Dynatrack record. In the new module, Dynatrack does not require the extra supply, so there is only one buffer per track.

The buffer amplifier consists of a bridging input transformer, a push-pull driver amplifier, and a push-pull output amplifier. A conventional coupling circuit is used to drive the heads.

The noise balance circuit in the bias supply has proven itself in the previous 3M machines. Its most important feature is that it uses the bias voltage to derive its own correction voltage. The correction only appears when the bias is energized so that there is no need to worry about introducing a permanent magnetization into the head.

The input impedance was kept as high as possible to provide for the possibility of a 16 track recorder in the future.

A -B SWITCH

A-B or source-tape monitor switching is accomplished by a relay on all 3M machines. This allows simultaneous switching of all tracks from a master button on the transport. Each module also has buttons so that each track can he switched on an individual basis.

POWER SUPPLY

A common power supply is used to feed all tracks of electronics. The supply contains two regulators - one for signal electronics, and the other for control circuits and light bulbs. This load division greatly simplifies the problem of eliminating clicks that might feed from relays or lights into the record or playback amplifiers. Each regulator has short circuit protection.

CONSOLE

Since the new modules are smaller than the current ones, it is now possible to use consoles with eight modules below the transport or eight modules in a mounting bay above the transport. One, two, three, and four track versions are also readily available.

When the modules are mounted above the transport, the console framework provides complete protection for all the connectors and cables. This allows the machine to sit flush against a wall and also permits the machine to be shipped laying on its back for added safety.

DISCRETE COMPONENTS VERSUS INTEGRATED CIRCUITS

Integrated circuits were investigated during the circuit design phase of development, but no competitively priced circuits were found that had the necessary power level, reserve capability, low noise performance, and low distortion. Most of the circuits were designed for applications where distortion is always present and 10% is maximum. In the future, better circuits will become available, but applications with 110 dB dynamic range, several watts output, and low distortion are still the province of discrete devices.

SUMMARY

The design of a low-cost electronics package for professional audio recorders does not necessitate any sacrifice in quality if the overall manufacturing efficiency of the package is optimized. The module described here demonstrated how this can be done by straightforward design if one allows a little imagination to aid the designer.

The module that is described here retains all of the features of the present version, but uses only 40% of the former board area, 30% of the former number of wires, and requires fewer hours to assemble. These improvements were achieved without any sacrifice in performance or dependability.

The author wishes to acknowledge the work of Don Kahn who deserves credit for many of the mechanical innovations incorporated into this new module.

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